*Reprinted from*

# DEPOSITIONAL ENVIRONMENTS OF THE LIGNITE-BEARING STRATA IN WESTERN NORTH DAKOTA

F.T.C. TING, EDITOR

Prepared for the Annual Field Trip,
Coal Geology Division,
Geological Society of America,
November 10-11, 1972

Guidebook No. 3
Department of Geology
University of North Dakota

Miscellaneous Series No. 50
North Dakota Geological Survey

# STRATIGRAPHIC POSITION OF LIGNITE BEDS IN THE TERTIARY ROCKS OF MERCER AND OLIVER COUNTIES

C. G. Carlson
North Dakota Geological Survey

## INTRODUCTION

Mercer and Oliver Counties are located in west-central North Dakota near the eastern margin of the lignite bearing Tertiary Formations. This geographic advantage plus the easy accessibility and thickness of some of the lignite beds led to early and continued exploitation. Surface mapping led to the naming of twenty-four lignite beds in Mercer and Oliver Counties, and many unnamed local beds have been mapped. Since 1932 Mercer County has been the leading county for lignite production in North Dakota with the exception of 1944, when it was second to Ward County. Oliver County was a minor producing area until the Minnkota plant began operations in 1970; now it is the second leading county. The bulk of the production in Mercer County has been from the Beulah-Zap bed while the Hagel bed is supplying the Minnkota plant.

The stratigraphic position of the lignite beds in this area and their relationship to lignite beds in other areas of the state have been continuing problems. The main problems of correlation and stratigraphic placement of the lignite beds are:

1) The variability in thickness of lignite beds. This is known from areas where continuous exposures or closely spaced drill hole information is available;

2) The lateral variability of lithology and thickness of the section between lignite beds;

3) Areas of drift covered bedrock or poor bedrock exposures;

4) Uncertainties about the thickness of the Sentinel Butte and Tongue River Formations; and

5) Uncertainties about the Sentinel Butte-Tongue River contact in areas other than along the Little Missouri River.

## PREVIOUS STUDIES

Most previous studies of the Tertiary rocks in Mercer and Oliver Counties have been primarily concerned with determination of the presence and thickness of the lignite beds. The general approach was usually to measure the thicknesses of lignite beds, name the beds, relate the lignite beds to each other by the stratigraphic interval between the beds or the interval above or below key "persistent" lignite beds using lithology and thickness of beds as tools of correlation. Recognizing the difficulties of correlation, most workers were content to apply local names when mapping

in the different geographic areas, sometimes suggesting correlations to other areas in their summaries. Using this approach Bauer and Herald (1925) mapped the lignite beds of the Fort Berthold Indian Reservation in northwestern Mercer County and adjacent areas and Andrews (1939) mapped the lignite beds of northeastern Mercer County and adjacent areas. Hancock (1926) mapped the lignite beds using letter designations in the New Salem lignite field, located just south of Oliver County. Benson (1952) mapped most of the lignite beds exposed in Mercer County, named some of the previously unnamed beds, arranged the lignite beds stratigraphically in the different geographic areas of his study (Table I), and suggested some correlations of beds to previous studies to the north and east. Johnson and Kunkel (1952) mapped the lignite beds of Oliver County, arranged them stratigraphically for the different geographic areas (Table II), and suggested correlations within these areas and with adjacent areas.

The uncertainty of extension of the Sentinel Butte-Tongue River contact into this area led Benson (1952, p. 42) to refer all of the strata between the Golden Valley and Cannonball Formations to the Tongue River Member of the Fort Union Formation, while Johnson and Kunkel (1959, p. 11) referred these strata to the Fort Union Formation. The key beds which they used for constructing stratigraphic sections were the Beulah-Zap, Stanton, Garrison Creek, Hagel, and Otter Creek beds. They then related their other named beds to these key beds by the stratigraphic interval above or below the key beds. Based on this approach Johnson and Kunkel (1959, p. 13) estimated a total thickness of the Fort Union (Sentinel Butte and Tongue River Formations of this study) Formation to be about 520 feet in Oliver County. In Mercer County, Benson (1952, p. 65) noted that based on piecing together his measured surface sections he had an estimated thickness of 550 to 575 feet for his Tongue River Member, but based on a few deep wells he estimated the thickness to be 750 to 800 feet.

Recognition of the Sentinel Butte and Tongue River Formations in western North Dakota has been based largely on color differences which are easily recognizable where good exposures are present along the Little Missouri River, although Royse (1967) used three criteria in his studies of that area. These were color differences, a lignite bed at the top of the Tongue River Formation, and a basal sandstone bed in the Sentinel Butte Formation. In Morton County, about 12 miles south of the southwest corner of Oliver County, the Sentinel Butte-Tongue River contact has also been mapped on the basis of color differences (Barclay, 1970, 1971) where there are good exposures in the Glen Ullin area. In that area there is no lignite bed nor basal sandstone bed present at the color contact, but his placement of the contact fits within the regional framework.

## Sentinel Butte and Tongue River Formations

Recognition of similar Sentinel Butte-Tongue River contacts in the Mercer-Oliver area is further complicated by glacial drift (Figs. 1 and 2) which obscures the contact in many areas, rates of erosion in some areas of good exposure which eliminates color differences, and a lack of color differences in test hole cuttings of these formations. In the Square Butte Creek drainage, where post-glacial drainage follows the preglacial drainage, exposures of the Tongue River Formation have weathered to light yellow and buff colors typical of the Tongue River Formation in the Little Missouri valley area. These colors

TABLE 1.-Named lignite beds and their relationship to "key beds" according to Benson (1952).

| WESTERN AREA | HAZEN AREA | STANTON AREA |
|---|---|---|
| **Golden Valley Formation** | | |
| **Shaffner bed**<br>30 feet above Alamo Bluff bed | **Beulah-Zap bed** | **Local bed**<br>50 feet above Stanton bed |
| **Alamo Bluff bed**<br>at base of upper member | 75 to 95 feet below Beulah-Zap bed<br>**Star bed** | **Stanton bed** |
| **Fort Union Formation** | 25 to 40 feet below Star bed<br>**Hazen "B" bed** | 35 to 40 feet below Stanton bed<br>**Coal Creek bed** |
| **Twin Buttes Bed**<br>130 to 150 feet above Beulah-Zap bed | 155 to 160 feet below Beulah-Zap bed<br>**Hazen "A" bed** | 85 to 95 feet below Stanton bed<br>**Knoop bed** |
| **Schoolhouse bed**<br>45 to 50 feet above Beulah-Zap bed; increasing westward to 80 to 100 feet | GARRISON AREA | 150 to 160 feet below Stanton bed<br>**Hancock bed** |
| **Beulah-Zap bed**<br>60 feet below Beulah-Zap bed | **Kruckenberg bed**<br>50 feet above Garrison Creek bed | BLACKWATER-EMMET AREA |
| **Spaer bed**<br>110 to 115 feet below Beulah-Zap bed | **Garrison Creek bed**<br>(?) position | **Beulah-Zap bed** |
| **Hazen "B" bed** | **Wolf Creek bed** | 160 to 165 feet below Beulah-Zap bed<br>**Garrison Creek bed** |

TABLE 2.-Named lignite beds and their relationship to "key beds" according to Johnson and Kunkel (1959).

| NORTHWEST AREA | CENTRAL AND NORTH-CENTRAL AREA |
|---|---|
| **Byer bed**<br>65 feet above Otter Creek bed | **Red Butte bed**<br>100 feet above Keuther bed |
| **Otter Creek bed**<br>135 to 145 feet above Beulah-Zap bed | **Keuther bed**<br>35 to 45 feet above Hagel bed |
| **Herman bed**<br>25 to 30 feet above Buckman bed | **Hagel bed**<br>25 to 40 feet below Hagel bed |
| **Buckman bed**<br>65 to 75 feet above Beulah-Zap bed | **Yeagher bed**<br>30 feet above Berg bed |
| **Schoolhouse bed**<br>30 to 45 feet above Beulah-Zap bed | **Berg bed**<br>40 feet above Stanton bed |
| **Beulah-Zap bed**<br>45 feet below Beulah-Zap bed | **Stanton bed**<br>20 to 45 feet below Stanton bed |
| **Spaer bed** | **Brahzda bed** |

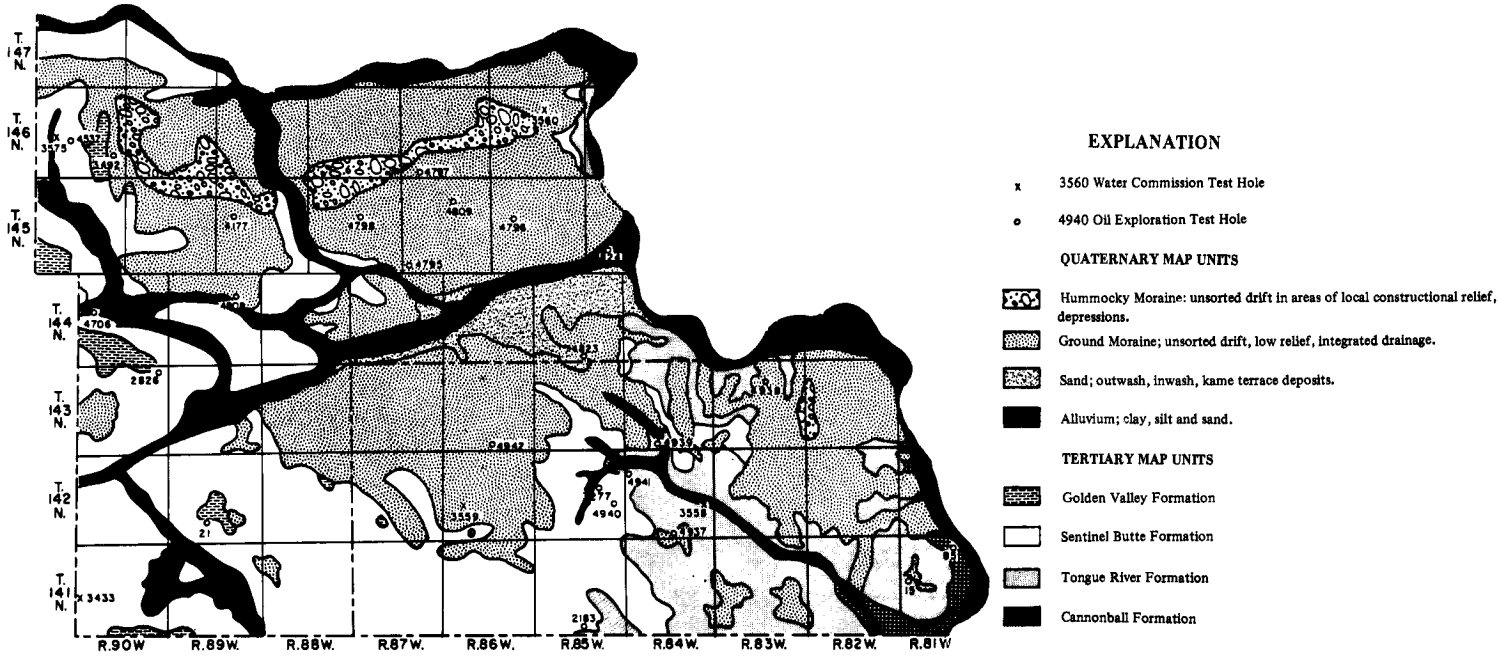



Figure 1. Geologic map of Mercer and Oliver Counties.

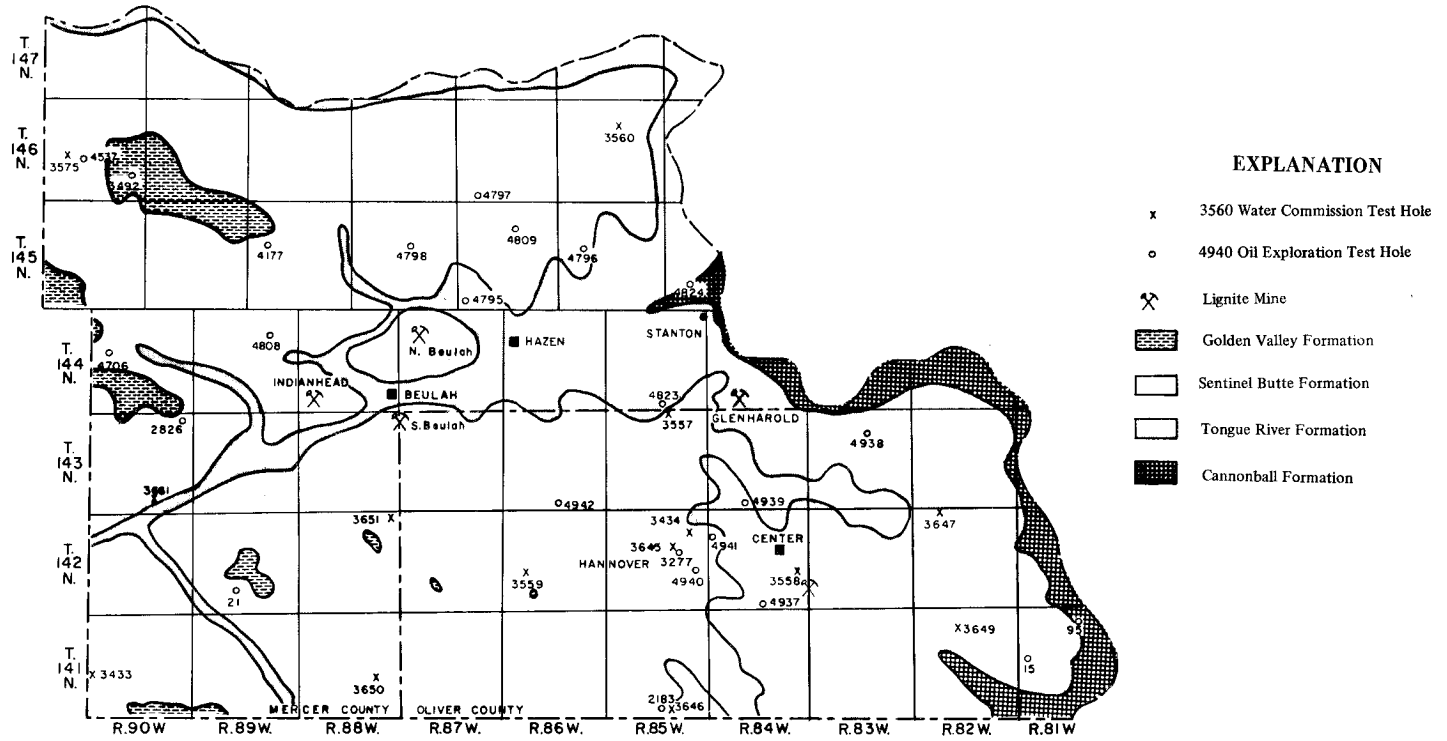
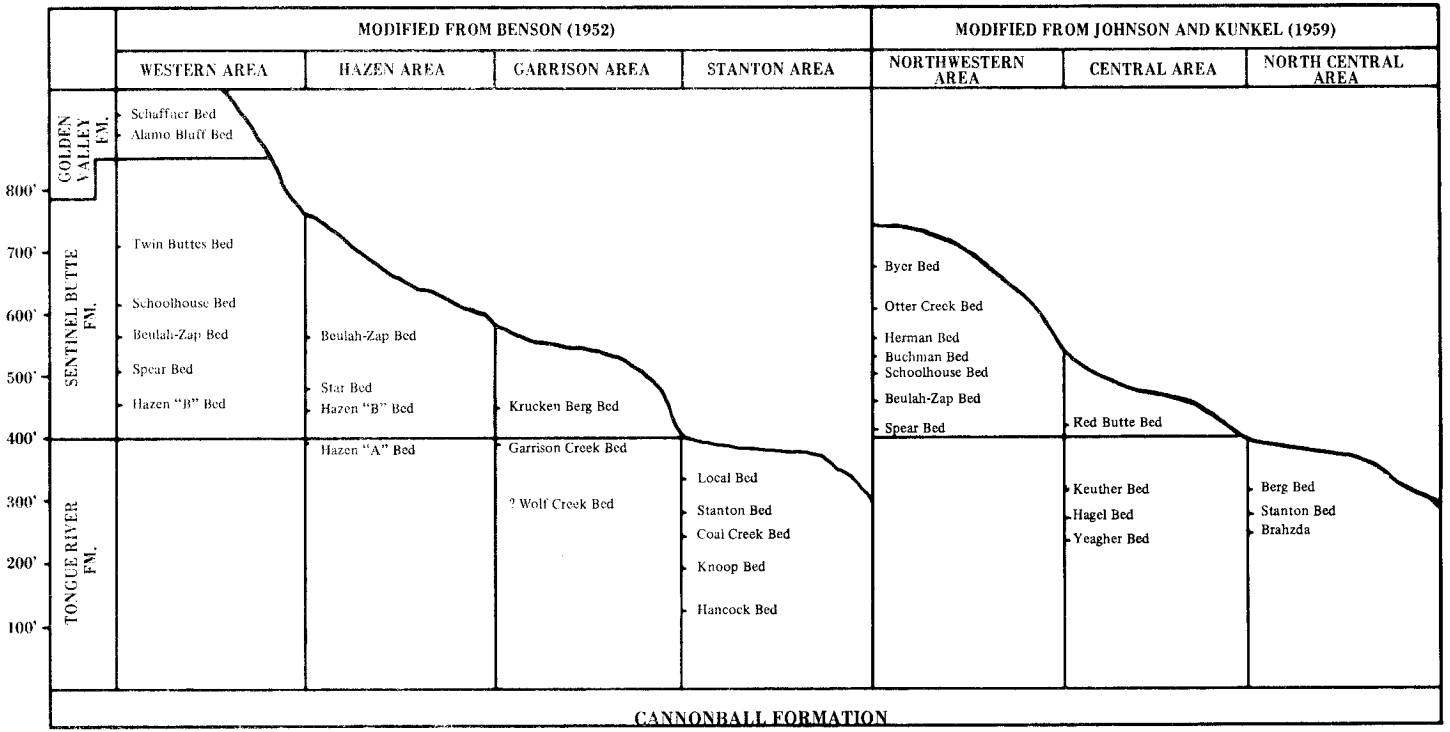



Figure 2. Bedrock geologic map of Mercer and Oliver Counties.


MODIFIED FROM BENSON (1952)
MODIFIED FROM JOHNSON AND KUNKEL (1959)
WESTERN AREA
HAZEN AREA
GARRISON AREA
STANTON AREA
NORTHWESTERN AREA
CENTRAL AREA
NORTH CENTRAL AREA
GOLDEN VALLEY FM.
SENTINEL BUTTE FM.
TONGUE RIVER FM.
800'
700'
600'
500'
400'
300'
200'
100'
Schaffner Bed
Alamo Bluff Bed
Twin Buttes Bed
Schoolhouse Bed
Beulah-Zap Bed
Spear Bed
Hazen "B" Bed
Beulah-Zap Bed
Star Bed
Hazen "B" Bed
Hazen "A" Bed
Krucken Berg Bed
Garrison Creek Bed
? Wolf Creek Bed
Local Bed
Stanton Bed
Coal Creek Bed
Knoop Bed
Hancock Bed
Byer Bed
Otter Creek Bed
Herman Bed
Buchman Bed
Schoolhouse Bed
Beulah-Zap Bed
Spear Bed
Red Butte Bed
Keuther Bed
Hagel Bed
Yeagher Bed
Berg Bed
Stanton Bed
Brahzda
CANNONBALL FORMATION

extend up to and above the Hagel bed in the area near Center. However, in the short drainages along the Missouri River trench from Hensler to Garrison Dam only a few of the exposed beds are of the typical Tongue River colors, although the Tongue River-Cannonball contact is present at the upper terrace level of the Missouri River just east of Hensler. Hence, the short drainages between Hensler and Stanton are eroding the same stratigraphic interval as that of the Square Butte creek drainage southeast of Center. The explanation for the lack of light colors in this area seems to be that these drainages are adjusting to the new base level, and the rate of erosion exceeds the rate of weathering so that the weathering effects (i.e., the light colors) are not present in this area.

Groundwater test holes (Croft, 1970), oil exploration test holes, and topographic mapping in Mercer and Oliver Counties now provide a framework for determining the thickness of the Sentinel Butte and Tongue River Formations. They also provide a means for relating the measured surface sections of the different geographic areas and placing the lignite beds in their proper stratigraphic position. Lacking the clear cut color differences of the Little Missouri area, the Sentinel Butte-Tongue River contact is somewhat subjective, so for mapping purposes it was placed at the base of sandstone beds which are present at many localities in about the right stratigraphic position to be at the contact based on subsurface information and topographic control.

A test hole in northwestern Mercer County (3575, 90-146-20 ccc) started in sand of the Sentinel Butte Formation at a surface elevation of 2,120 feet. The Golden Valley Formation crops out about one mile east of this test hole at only a slightly higher elevation, so a nearly complete Sentinel Butte-Tongue River section was present at this site. The Cannonball Formation was penetrated at a depth of 960 feet, so a maximum thickness for the Sentinel Butte-Tongue River interval in this area is about 1,000 feet. Part of the nonmarine section above the Cannonball may belong in the Ludlow Formation which would then thin the Sentinel Butte-Tongue River interval by perhaps as much as 100 to 150 feet. Samples from this test hole show 15 separate lignite beds above the Cannonball of which 4 appear to be more than 5 feet thick based on logs and samples. Correlations of these lignite beds to named beds of surface studies is uncertain because of distances to areas of mapped beds with topographic control, but based on regional dip the lignite bed at about 240 feet may be equivalent to the Beulah-Zap bed. If this correlation is correct, the Beulah-Zap bed is about 275 feet below the top of the Sentinel Butte Formation.

A test hole south of Beulah (3651, 88-142-1 cdc) was drilled from a surface elevation of 2,075 feet to a depth of 640 feet with the lower 30 feet logged as Cannonball Formation. The base of the Golden Valley Formation is present at elevations of 2,110 feet in Sections 10 and 11, T. 142 N., R. 88 W, where it lies on silts and clays of the Sentinel Butte Formation. It is difficult to be certain of the Tongue River-Cannonball contact when so short a section of Cannonball is cut, but if the call is correct, then the total Sentinel Butte-Tongue River section has thinned to about 700 feet. It seems likely that it is thicker and that the test hole did not penetrate Cannonball. A 20-foot thick lignite is present at a depth of 250 to 270 feet, and a 10-foot thick lignite bed is present at a depth of 95 to 105 feet. Based on elevation and thickness the 10-foot thick bed is the Beulah-Zap bed of the South Beulah mine area (test holes are about 2.5 miles away). This

places the Beulah-Zap bed about 130 feet below the top of the Sentinel Butte Formation in this area.

A test hole (3557, 85-143-3 dad) was drilled about 3.5 miles west of the Glenharold mine where the Hagel bed is being mined. Glacial drift is present at the surface here and overlies the lower 357 feet of the Tongue River Formation. This test hole penetrated a 5-foot thick lignite bed 170 feet above the base of the Tongue River Formation and a 6-foot thick lignite bed 245 feet above the base of the Formation. The base of the Hagel bed was 275 feet above the base of the Tongue River Formation at an elevation of 1,850 feet. These were the only significant lignite beds penetrated in this test hole. Surface elevations of bedrock on the drainage divide about three miles south of this test hole are as high as 2,330 feet with no Golden Valley Formation present. Therefore, the total thickness of the Sentinel Butte and Tongue River Formations in this area was at least 750 feet thick and the Hagel bed is about 480 feet below an eroded top of the Sentinel Butte Formation.

A test hole (3646, 85-141-27 ddd) was drilled about ten miles north of New Salem. Bedrock is present at the surface at this location, and the Tongue River-Cannonball contact was penetrated at a depth of 404 feet. A 3-foot thick lignite bed (the Hagel ? bed) was present 270 feet above the base of the Tongue River Formation and a 12-foot thick lignite bed was present 80 feet above the base of the Tongue River Formation. No other lignite beds exceeding 2.5 feet in thickness were present in this test hole.

## CONCLUSIONS

This information leads to the conclusion that surface mapping studies might be misleading in terms of the number of lignite beds expected to be present at any one locality. It also indicates that the estimated thickness for the Sentinel Butte-Tongue River interval based on surface exposures were generally thinner than those present in the test holes.

In northwestern Mercer County the Sentinel Butte-Tongue River interval is at least 850 feet thick, and may be as much as 1,000 feet thick; eastward it thins to about 750 feet in the Beulah-Hannover area where the Golden Valley Formation is present. Where the Golden Valley Formation is absent the thickness varies with most of the thinning accounted for by erosion of the Sentinel Butte Formation until the erosional edge is reached in central Oliver County, and then the Tongue River Formation thins eastward due to erosion.

Benson (Table I) did not attempt to correlate between the Hazen-western area where he used the Beulah-Zap bed as his key bed and the eastern area where he used the Stanton bed as his key bed. Johnson and Kunkel (Table II) also used different key beds in the different areas of their study, but they (1959, p. 35) then attempted to correlate key beds between these areas. They correlated the Hagel bed of the Square Butte drainage with Bed D of the New Salem study and to the Otter Creek bed of their northwestern area. Based on test hole data and topographic control some adjustments of these correlations now seem probable. Table III is my interpretation of the stratigraphic position of the previously named beds in Mercer and Oliver Counties.

In the Square Butte creek drainage there are nearly continuous bedrock exposures from the Cannonball-Tongue River contact to the area northwest of Center, so the position of the Hagel "key" bed was given as about 240 feet above the base of the Tongue River Formation based on surface mapping. Test hole 3558 (142-84-24 bba) penetrated the Cannonball Formation at a depth of 305 feet from a surface elevation of 2006 feet, so the base of the Tongue River Formation is at an elevation of about 1700 feet. Test holes 1 to 1.5 miles south and west of this test have the base of the Hagel bed at elevations of about 1,985 feet, or about 285 feet above the base of the Tongue River Formation.

Glacial drift caps the drainage divide between Square Butte Creek and the short drainages cutting back from the Missouri River trench, so direct correlations across this divide are not possible; and correlation between exposures in each of the drainages is difficult because of the lateral variability. In this area topographic maps furnish elevations of the exposures as well as the Tongue River-Cannonball contact. This information combined with test hole data furnishes the regional dip of the Tongue River-Cannonball contact and provides a means of placing the lignite beds in their proper stratigraphic position. The lignite bed which is being mined at the Glenharold mine was mapped as the Stanton bed by Benson (1952) as well as Johnson and Kunkel. Based on test hole 3557 this bed is about 275 feet above the base of the Tongue River Formation and is in the stratigraphic position if not a physical equivalent of the Hagel bed of the Center area (Table III).

In the western area (Otter Creek drainage) another problem in correlation arises from the naming of the Herman bed. This bed was mapped only on the west side of Otter Creek and the exposure at locality 21 (Johnson and Kunkel, 1959, p. 44) is equivalent to the Beulah-Zap bed of the south Beulah mine based on topographic control and drill hole information now available. This introduces some confusion in Johnson and Kunkel's western area as either their sections based on key beds (i.e., Otter Creek and Beulah-Zap) are in error or there are errors in correlation to Benson's Knife River beds. Recognizing the difficulties of correlations based on lithology and thickness of beds, it seems best to use their names and measured sections for the Otter Creek drainage and adjust the stratigraphic position of the beds based on Herman bed = Beulah-Zap of Benson (Table III, western area).

In the Beulah area the Beulah-Zap bed is about 130 feet below the top of the Sentinel Butte Formation. The Herman bed (Beulah-Zap of Benson) then is about 130 feet below the top of the Sentinel Butte Formation, and the Otter Creek bed is about 80 feet below the top of the Sentinel Butte Formation. Since the Hagel bed is at least 480 feet below the top of the Sentinel Butte Formation, then the Otter Creek bed is actually about 400 feet higher stratigraphically than the Hagel bed rather than a lateral equivalent as suggested by Johnson and Kunkel. This miscorrelation would also account for much of the discrepancy in thickness between their estimated thickness of about 520 feet and the actual thickness of 750 to 800 feet for the Sentinel Butte and Tongue River Formations in this area.

The test hole information indicates that most of the lignite beds do not extend over wide areas and that correlations based on matching of measured surface sections is difficult. The practice of naming beds in different

geographic areas without regard to correlation to adjacent areas has the advantage of not having the same name applied to different beds because of miscorrelations. When subsurface information permits reliable correlations it may be advantageous to recognize where the same bed has received different names (e.g., Hagel = Stanton, Herman = Beulah-Zap of Benson, ?Hazen B = Beulah-Zap of Johnson and Kunkel). However, the arrangement of the named beds in Table III is not intended to suggest that named beds present in different areas at about the same stratigraphic horizon should be correlated as one and the same bed. Rather, it is only intended to show the approximate position of these beds with respect to their position within the Sentinel Butte and Tongue River Formations.

## SELECTED REFERENCES


Andrews, D. A., 1939, Geology and coal resources of the Minot region, North Dakota: U. S. Geol. Survey Bull. 906-B, p. 43-84.

Barclay, C. S. Venable, 1970, Preliminary geologic map of the Glen Ullin quadrangle, Morton County, North Dakota: U. S. Geol. Survey, open file map.

Barclay, C. S. Venable, 1971, Preliminary geologic map of the Dengate quadrangle, Morton County, North Dakota: U. S. Geol. Survey, open file map.

Bauer, C. M., and Herald, F. A., 1921, Lignite in the western part of the Fort Berthold Indian Reservation, South of Missouri River, North Dakota: U. S. Geol. Survey Bull. 726-D, p. 109-172.

Benson, W. E., 1952, Geology of the Knife River area, North Dakota: U. S. Geol. Survey, open file report, 323 p.

Carlson, C. G., in press, Geology of Mercer and Oliver Counties: North Dakota Geol. Survey Bull. 56, pt. I and North Dakota State Water Comm. County Ground Water Studies no. 15, pt. I.

Croft, M. G., 1970, Ground water basic data, Mercer and Oliver Counties, North Dakota: North Dakota Geol. Survey Bull. 56, pt. II, and North Dakota State Water Comm. County Ground Water Studies no. 15, pt. II, 268 p.

Hancock, E. T., 1921, The New Salem lignite field, Morton County, North Dakota: U. S. Geol. Survey Bull. 726-A, 39 p.

Johnson, W. D., Jr. and Kunkel, R. P., 1959, The Square Buttes coal field, Oliver and Mercer Counties, North Dakota: U. S. Geol. Survey Bull. 1076, 91 p.

Royse, C. F., Jr., 1967, Tongue River-Sentinel Butte contact in western North Dakota: North Dakota Geol. Survey Rept. Inv. 45, 53 p.